UNCLASSIFIED

AD NUMBER
AD319468
CLASSIFICATION CHANGES
TO: **UNCLASSIFIED**
FROM: **RESTRICTED**
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Controlling DoD Organization: Army Standardization Group, UK, Box 65, USN 100 FPO NY.**
AUTHORITY
DSTL, DEFE 15/2172, 11 Dec 2008 ; DSTL, DEFE 15/2172, 11 Dec 2008

THIS PAGE IS UNCLASSIFIED

Cy. No. 61
Reg. 14342
19 December 1960
BRL

43/60

RESTRICTED

COPY NO. 61

THE WAR OFFICE

ARDE
M(MX)43/60

ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

MATERIALS EXPLOSIVES DIVISION

A.R.D.E. MEMORANDUM (MX) 43/60

Solid Propellant Power Cartridges - Some Principles of Design

H. D. Warwick

Gn/5030-2

Fort Halstead.
Kent

RESTRICTED

Sept,
1960

This Document was graded
RESTRICTED
at the 132nd meeting of the A.R.D.E.
Security Classification Committee.

RESTRICTED

The War Office

ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

A.R.D.E. MEMORANDUM (MX) 43/60

Solid Propellant Power Cartridges - Some Principles of Design

H. D. Warwick (X4)

Summary

Solid propellant power cartridges are now commonly used as convenient forms of packaged power for turbine mechanisms such as Engine Starters, piston mechanisms such as Ejector Release Units and Pilot Ejector Seats, and fluid ejection systems, and the field of application of such cartridges continues to increase.

The aim of this report is to outline in the simplest terms the essential principles and problems associated with the design of such cartridges.

Relevant reports are referred to in the text but data from them are not, in general, repeated; a list of these references is also given.

Approved for issue:

L. Northcott, Principal Superintendent 'MX' Division

RESTRICTED

CONTENTS

		Page
1.	Introduction	1
2.	Main charge	1
	2.1. Charge characteristics	1
	2.2. Propellants	2
	2.3. Inhibition	4
3.	Ignition	4
4.	Cartridge case	5
5.	Compatibility	5
6.	References	6

IMPORTANT

This document should be returned to the Reports Officer, Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, when no longer required.

INITIAL DISTRIBUTION

Internal

No. 1	Director
2	Deputy Director
3	PS/MX
4	PS/B
5	PS/P
6	Dr. W. M. Evans
7	S/X4
8-10	X4 (Att. Mr. S. C. Bridges, Lt.Col. G. N. Barlow Mr. H. D. Warwick)
11-12	X4 Library

External UK

13	DGSR(M)
14	DG of A/Admin.
15	D of A (R&D)
16-17	DERDE
18	DRAE
19	DRPE
20	DA Arm.
21	D Eng.RD
22	DMXRD
23	DI Arm
24	DOF/Amm.
25	DOF/F
26	DGW(S)
27	Sec. OB
28	SROF Bishopton
29	SROF Blackburn
30	SROF Chorley
31	SROF Radway Green
32	ICI Ltd., Nobel Division, Stevenston
33	M.L. Aviation Company Ltd., The Aerodrome, White Waltham, Maidenhead
34-35	TIL - for retention

Overseas (through TIL)

36	BJSM/DRS (Att. Director of Munitions)
37	UK/MOAS Ottawa, (Att. Mr. F. S. Barton)
38-42	Canada - Dept. Nat. Def.
43	- Nat. Res. Council
44-47	- Def. Res. Liaison
48	- CALE
49-53	Australia - Sen. Rep.
54	- RAAF Overseas Hq., London
55	- DSL
56	- SRLO
57-74	USA - Joint Reading Panel
75	- Assist. Sec. of Def. for Res. & Dev.
76-77	- ONR London

Stock

78-87

1. INTRODUCTION

A power cartridge is, as the name implies, a unit of packaged power. This power can be provided in many ways; it can be developed at high or low pressure, it can extend over long or short times. As will be seen later, cartridges can be designed to give constant pressure over a given time, a rising pressure or falling pressure, and variations on these by combination of the principles involved.

Of first importance in a power cartridge is the source of power which is the main charge of propellant, but it must be ignited before it can release its energy and an igniter is therefore necessary. Finally, the charge and its means of ignition must be housed in a suitable container.

The sections which follow will be divided broadly under these headings with sub-division as required to deal with ancillary matters.

2. MAIN CHARGE

Before the design of the main charge can be started it is necessary to know the amount of energy required from it, and how this energy is to be released in order that a preliminary assessment of charge weight and shape can be made. An estimate of the weight of the charge required is then made on the assumption that approximately 100,000 ft. lb . of work can be obtained from 1 lb. of propellant. The subject of charge design is dealt with in some detail in References 1, 3 and 4, but some basic facts follow :-

2.1 Charge Characteristics

The form which the charge will take can be assessed from a knowledge of the pressure/time curve expected from the charge geometry. The characteristics of the basic forms of charges are shwon in figures 1(a) - (d) and Table 1 below:

Table 1 - Characteristics of Basic Charge Designs

Do = External diameter of charge in inches

Di = Internal diameter of charge in inches

L = Length of charge in inches

BR = Burning Rate (inches/sec.) at the pressure of operation. Since a constant pressure of operation is not normally achieved a mean figure for burning rate must be used.

Charge	Type of P/T curve	Time of burning	Remarks
Cord	Falling	$\frac{Do}{2BR}$	L> Do
Tube	Falling tending to constant	$\frac{Do-Di}{4BR}$	(1) L> $\frac{1}{2}$(Do-Di) (2) Short times only (3) For L>>$\frac{1}{2}$(Do-Di)
Tube inhibited on curved surface	Rising	$\frac{Do-Di}{2BR}$	L> Do-Di
Cigarette	Constant	$\frac{L}{BR}$	Long times possible

2.1.1 Cord Charge

This is the simplest form of all being a solid cylinder of propellant: its applications are few but an important one is the initiation of an isopropylnitrate (I.P.N.) gas generating system in which the supply of the I.P.N. is controlled by a pressure sensitive device. In such a system the pressure from the initiating charge starts the supply of the I.P.N. whilst the heat from the charge causes it to dissociate: this augments the pressure and unless the charge has a falling p/t characteristic an excess pressure could occur which in turn would operate a safety device, cut off the I.P.N. supply and lead to early failure of the system to become self sustaining.

2.1.2 Tubular Charge

This is probably the most common form of charge used in power cartridges. As will be seen from Figure 1(b) the pressure falls because of the "end effect": as the L/Do ratio is increased so does the pressure tend to a constant value.

2.1.3 Tubular Charge inhibited on the external curved surface

Apart from the fact that this type of charge gives a longer time of burning than a tube of the same external diameter, it also has an advantage compared with a similar cord, since the initial pressure is reduced by a factor dependent upon the inside diameter of the inhibited tube.

Figure 1(c) shows the rising characteristic of this type of charge with the sinous shape which derives from the end effect. As Lo/Do is increased the curve tends to a straight line.

2.1.4 Cigarette burning charge

This is a cord inhibited over its curved surface and one end. Charges of this type have been developed which give burning times of 200 secs. Applications are, for example, power supply units such as those for electrical and hydraulic supplies in Guided Weapons where in general the gases may be used to drive a hydraulic pump or an alternator.

Inhibition has been mentioned in paragraphs 2.1.3 and 2.1.4 above, and will be dealt with further in a later section.

2.2 Propellants

The number of propellants available from Ministry and trade sources is considerable; other than in exceptional circumstances the choice will, however, be made from the six propellants selected for the Standard Range of Power Cartridges. Details of these are given in Table 2 below.

TABLE 2 PROPELLANT DATA

Propellant	Cal. Value	Burning Rate
F 488/1079	680	.28 - .21 at 800 - 1100 p.s.i. (Platonised)
F 547/18	480	.14
F 547/36	250	.10
F 547/152	645	.14 - .15 at 400 - 1000 p.s.i. (Platonised)
"Coolite"	200	.08
F 547/72	730	.175 at 600 to 1000 p.s.i.(Platonised)
Calorimetric values are in calories per gramme. Burning rates are in inches per second at 1000 lb/in^2 unless stated otherwise		

These propellants are of two main types (a) unplatonised or normal and (b) platonised, the difference being that a normal propellant obeys a simple index law of burning rate as a function of pressure so that the burning rate rises continually as pressure is increased. The burning rate curve for a platonised propellant however, exhibits a region or plateau over which the pressure remains sensibly constant and independent of pressure. There are also "mesonic" propellants for which over a specific region of the burning rate curve the rate falls with increasing pressure. These effects are achieved by the addition of certain salts to the normal type of propellant formulation.

The first choice of propellant might often appear to be one with a high calorimetric value and which is also platonised. Due regard must be paid, however, to the system in which the cartridge will be used. High calorimetric values are associated with high gas temperatures and a platonised propellant will generally give higher gas temperatures and increased erosion compared with normal propellants of the same calorific values. As a general rule platonised propellants should not be used for applications where repeated shots are required, as for instance direct turbine type starters for aircraft engines, where a life of some 500 shots is generally required.

An approximate value for the uncooled gas temperature can be obtained from the empirical formula:-

Temperature in degrees C = 2.45 x calorimetric value (calories/gramme) + 360 for non-platonised propellants. To this value should be added a further 150 to 200°C for platonised propellants.

It will be appreciated however, that this "uncooled" temperature only applies to the gas in the near vicinity of the cartridge, and that in most applications the cooling is severe, so that the mean gas temperature of operation rarely exceeds one half of its uncooled value, and in many instances will be as little as a fifth of it.

One particularly important cooling effect derives from the materials of the case in which the propellant is housed. Although metal cases are now always used in Service applications, experimental work and final designs have in the past been frequently based on cardboard cases. The difference in cooling between the two types of case is equivalant to about 10% of the charge weight and this can in some instances render it impossible to translate a cardboard case design into a metal one of the same dimensions. In general the various classes of application of power cartridges fall in this respect in the following order, the "hottest" or most efficient operation being given first - it will be noted that this order also tends to follow the time of operation. In power cartridges efficiency is however rarely of prime importance, the compactness of the source of power and their characteristics usually being the overriding factors.

(a) Ejector Release Units which approach a gun type application in time of operation,

(b) Engine Starter applications,

(c) Fluid ejection systems - piston operated,

(d) Fluid ejection systems - direct application.

Few data are available on the actual gas temperatures experienced in various types of equipment, but an experimental programme on this problem is now in hand at Messrs. Imperial Chemical Industries Limited under extral-mural contract from the A.R.D.E.

The burning rates of non-platonised propellants are normally quoted at 1000 p.s.i. and are a function of the pressure. In Ref. 1, burning rate curves are given of propellants, as well as the burning rate index from

which the variation of burning rate with temperature can be determined.

A typical burning rate curve for mesonic propellant is shown in Figure 1(e). It will be seen that such a propellant tends to be self controlling when burning in the platonised region.

2.3 Inhibition

By inhibition is meant the prevention of burning on one or more surfaces of the charge. The effect of inhibition has been indicated in paragraphs 2.1.3 and 2.1.4 above.

No fully acceptable material has yet been found for use in power cartridges; "Plastic Q" (cellulose acetate) is the only material in use at present: LPCA (low plasticised cellulose acetate) and EC (ethyl cellulose) have also been examined. All of these materials absorb nitroglycerine from double based propellants thus degrading the propellant and the coating: "Plastic Q" absorbs up to some 57% of its own weight, EC about 15% of its own weight with LPCA intermediate. From this point of view EC would appear the most suitable but it has been abandoned due to the nature of its residues after burning. Tests with LPCA are continuing. In the meantime it has been shown that "Plastic Q" with the further protection given by tape wrapping forms a satisfactory inhibition medium, although it has a limited life.

In general, it is best to use charge designs in which inhibition is not required as apart from the problems of finding suitable materials the inhibitor, particularly with the secondary protection afforded by tape wrapping, occupies a not inconsiderable amount of space, thus reducing the size of charge which can be accommodated in a given case.

3. IGNITION

Initiation can be by electric or percussion cap but there is usually insufficient energy in the cap to ignite the main charge, and an intermediate or igniter charge of gunpowder is normally employed. The functions of this igniter charge are to light the main charge and also rapidly to raise the pressure to the operational value required for the application.

In some cases where the system approaches that of a vented vessel it is also necessary to be sure that the pressure is rapidly brought above its critical value, that is the pressure below which stable burning does not take place. In other cases particularly in fluid ejection application the problem of critical pressure does not arise and stable burning can be achieved at all pressures from atmospheric upwards.

Pressure build up can be assisted by incorporating a closure disc which will rupture at a suitable pressure (above the critical pressure if that is important), or by the use of a nozzle. In the former case care must be taken to ensure that the rapid change in volume which will occur when the closure disc bursts, does not bring about a drop in pressure to a point at which the main charge will "go out". In the latter case sufficient igniter material will be required to give the required pressure rise against the loss of gas through the nozzle.

An initial assessment of igniter material required can be made from the knowledge that 1 gramme of gunpowder will give 270 ccs of gas at NTP and that in the time concerned little cooling will have taken place so that the volume of hot gas can be taken as five times this figure or 1350 ccs. The largest practicable grain sized gunpowder should be used to obviate high peak pressures at commencement of ignition, though these are not always due to the igniter material. Woolcock's paper (Ref.2) deals with the subject of ignition at some length, but it should be noted that ignition presents complex basic problems which are still not fully understood.

Caps for initiation should be chosen from the percussion cap QV5AF as used in N.A.T.O. standard 7.62 mm ammunition or the 18 volt conducting composition cap ARM69964. The percussion cap requires a minimum strike energy of 56 inch ozs at a minimum velocity of 6ft/sec. and a hard hemispherical ended striker of .045 inch diameter, and if any of these conditions is not fulfilled misfires inevitable occur. The 18 volt conducting composition cap can normally be operated on a standard aircraft 24 volts supply with a 10 ohm series resistor, the latter being fitted to protect the aircraft electrical system in the event of the cap presenting a dead short on firing. This cap in its service form cannot be guaranteed to provide a gas tight joint in the base of the case, and is therefore not entirely suitable for use in cartridges for high altitude applications. Improved caps are now under design.

4. CARTRIDGE CASE

The essential features of the cartridge case are that it should house the main propellant charge and its ignition system in such a manner that the whole will withstand the full range of environmental tests which include rough usage and climatic storage.

A cartridge case consists of the body which accepts the igniter at one end, and the mouth closure which incorporates the closure disc at the other. Particular features of the system are that the charge is carried between buttresses at the igniter end of the case and shoulders on the grid of the mouth closure: this ensures good conditions of gas flow at both ends of the case as well as good ignition and freedom from blocking the mouth.

A standard range of such cartridges is under development based on 14 diameters of impacted extruded aluminium bodies from $\frac{1}{2}$ inch to $5\frac{3}{4}$ inches inclusive. It is intended also to standardize the mouth closure components and a range of primers. This system is described in detail in "A Standard Range of Solid Propellant Power Cartridges" by Hill, and "A Users Guide to the Standard Range of Solid Propellant Power Cartridges" by Hill and Warwick, (Ref. 3 and 4). A suitable size of case should be chosen from this range.

Mention has been made in paragraph 3 of the closure disc and the part it takes in the ignition of the main charge; the main function is however, to close the cartridge. In some types of breech system there is more than one cartridge to permit several operations of the equipment without the need for reloading. In breeches where the chambers housing the cartridges are interconnected it can be seen that the pressure generated on firing one will act upon adjacent cartridges, and must be held by their closure discs. In such cases, it is necessary to provide an internal annular support for the disc so that although it will rupture at the correct internal pressure it will not fail under a higher pressure applied externally.

Care must be taken that the nature of the closure is not such as will introduce undesirable debris into the system - some systems are far more critical than others in this respect. To this end also the generated gases should not be allowed to pass over any part of the mouth of the aluminium alloy case; components used at this end of the case should wherever possible be made from mild steel.

5. COMPATIBILITY

There are two main factors under this heading. One is the effect of the materials of construction upon the explosive fillings, and the other is the effect of the explosive fillings on materials used for construction. Possible effects must be checked for all materials and conditions of use. Some plastic materials for example will drastically reduce the life of double based propellants usually due to interchange of the plasticisers between the plastic and the propellant; this can also cause the plastic to soften. In some cases however, effects are unilateral and in many others such difficulties only arise in the presence of moisture. Further details are contained in reference 5.

The terms "contact" and "proximity" will be found in work concerned with compatibility and are self explanatory. It must be remembered however, that a material which is found to be compatible in a particular application must be taken into a filling factory at some stage in the production of a cartridge and the possibility of inadvertent contact with explosives, other than the one for which it is accepted, must always be borne in mind.

6. REFERENCES

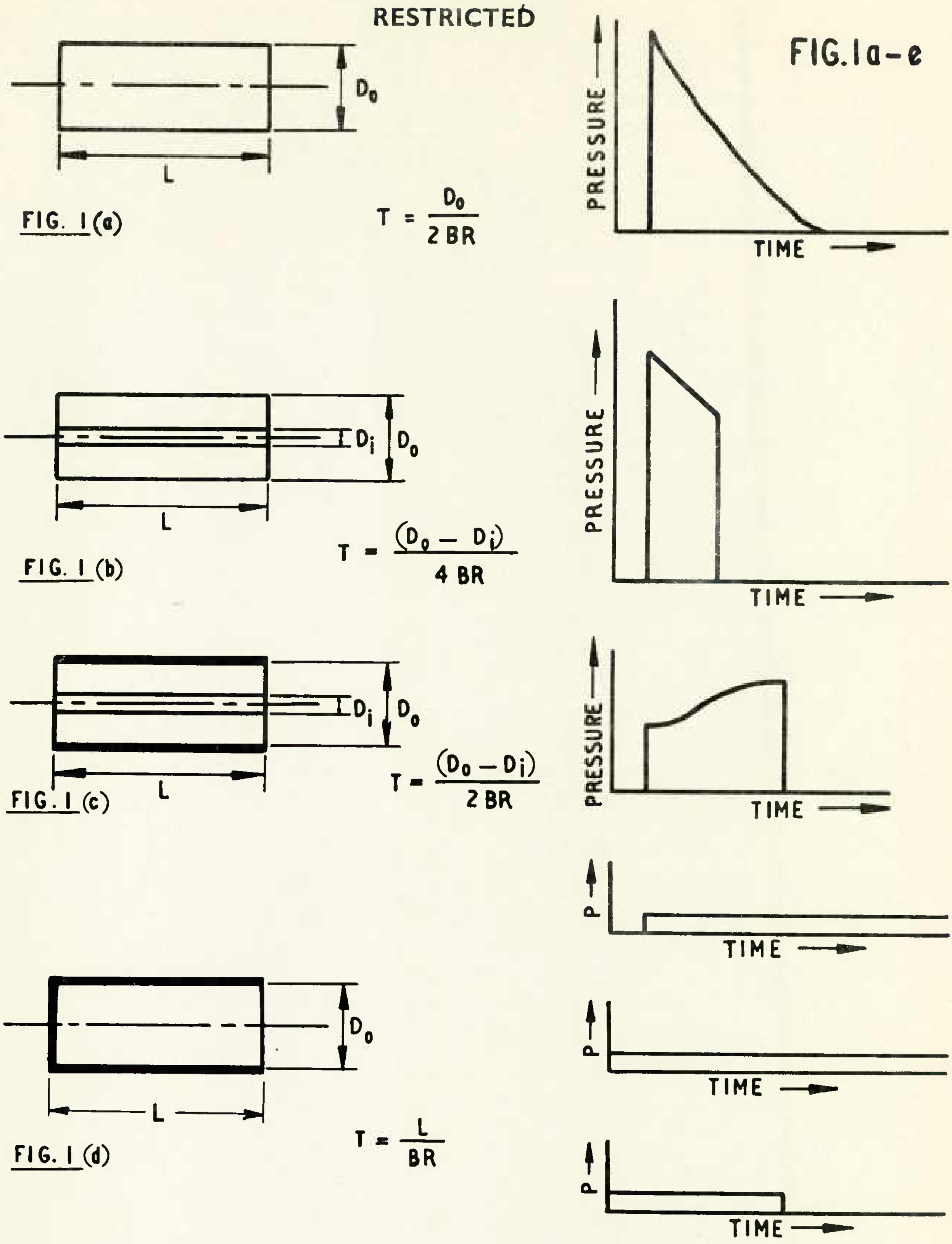
1. Power Cartridges, Some Principles of Charge Design - F.H. Seeley ARE Report 24/54.

2. Some Aspects of Ignition and Abnormal Burning of Solid Propellant Rocket Charges - J.U. Woolcock, ARDE Memorandum (P) 45/58.

3. A Standard Range of Solid Propellant Power Cartridges - W.G. Hill ARDE Memorandum (MX) 7/60.

4. A Users Guide to the Standard Range of Solid Propellant Power Cartridges - W.G. Hill and H.D. Warwick, ARDE Memorandum (MX) 6/60.

5. Notes on the Compatibility of some materials with solid explosives - E. Brown, Technical Note No. 7/TN/57 of ERDE.



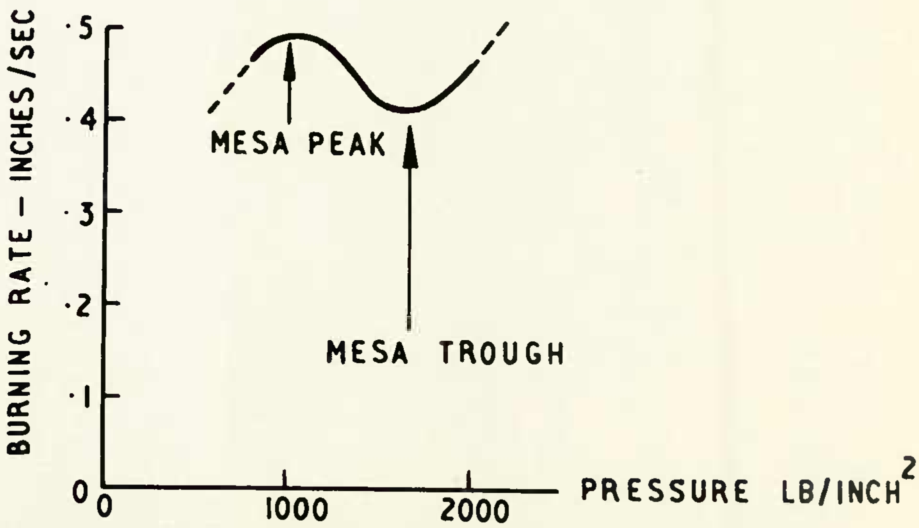


FIG. 1(e) TYPICAL BURNING RATE CURVE FOR 'MESONIC' PROPELLANT

FIG. 1 TYPICAL P/T CURVES

ALL CHARGES HAVE SAME EXTERNAL DIMS & P/T CURVES ARE TO THE SAME SCALE.

For Indexing

RESTRICTED

Armament Research & Development Establishment 62-573
A.R.D.E. Memorandum (MX)43/60 662.3

Solid propellant power cartridges - Some principles of design.
H.D.Warwick. August 1960

Solid propellant power cartridges are now commonly used as convenient forms of packaged power for turbine mechanisms such as Engine Starters, piston mechanisms such as Ejector Release Units and Pilot Ejector Seats, and fluid ejection systems, and the field of application of such cartridges continues to increase.

The aim of this report is to outline in the simplest terms the essential principles and problems associated with the design of such cartridges.

Relevant reports are referred to in the text but data from them are not, in general, repeated; a list of these references is also given.

6pp. 1 fig. 2 tabs. 5 refs. RESTRICTED

RESTRICTED

Armament Research & Development Establishment 62-573
A.R.D.E. Memorandum (MX)43/60 662.3

Solid propellant power cartridges - Some principles of design.
H.D.Warwick. August, 1960

Solid propellant power cartridges are now commonly used as convenient forms of packaged power for turbine mechanisms such as Engine Starters, piston mechanisms such as Ejector Release Units and Pilot Ejector Seats, and fluid ejection systems, and the field of application of such cartridges continues to increase.

The aim of this report is to outline in the simplest terms the essential principles and problems associated with the design of such cartridges.

Relevant reports are referred to in the text but data from them are not, in general, repeated; a list of these references is also given.
6pp. 1 fig. 2 tabs. 5 refs.

RESTRICTED

Armament Research & Development Establishment 62-573:
A.R.D.E. Memorandum (MX)43/60 662.3

Solid propellant power cartridges - Some principles of design.
H.D.Warwick. August, 1960

Solid propellant power cartridges are now commonly used as convenient forms of packaged power for turbine mechanisms such as Engine Starters, piston mechanisms such as Ejector Release Units and Pilot Ejector Seats, and fluid ejection systems, and the field of application of such cartridges continues to increase.

The aim of this report is to outline in the simplest terms the essential principles and problems associated with the design of such cartridges.

Relevant reports are referred to in the text but data from them are not, in general, repeated; a list of these references is also given.
6pp. 1 fig. 2 tabs. 5 refs.

RESTRICTED

RESTRICTED

Armament Research & Development Establishment 62-573:
A.R.D.E. Memorandum (MX)43/60 662.3

Solid propellant power cartridges - Some principles of design.
H.D.Warwick. August,1960

Solid propellant power cartridges are now commonly used as convenient forms of packaged power for turbine mechanisms such as Engine Starters, piston mechanisms such as Ejector Release Units and Pilot Ejector Seats, and fluid ejection systems, and the field of application of such cartridges continues to increase.

The aim of this report is to outline in the simplest terms the essential principles and problems associated with the design of such cartridges.

Relevant reports are referred to in the text but data from them are not, in general, repeated; a list of these references is also given.
6pp. 1 fig. 2 tabs. 5 refs.

RESTRICTED

CONFIDENTIAL
MODIFIED HANDLING AUTHORIZED

U.S. ARMY STANDARDIZATION GROUP, U.K.
Box 65, USN 100, F.P.O.
New York, N.Y.

GM-RP-2819

5 December 1960

SUBJECT: Transmittal ARDE Memo (MX)43/60 (U)

TO: Commanding Officer
U.S. Army Ordnance Technical Intelligence Agency
Arlington Hall Station
Arlington 12, Virginia

Forwarded herewith as Inclosure No. 1 for your retention is Armament Research and Development Establishment Memorandum (MX) 43/60, entitled, "Solid Propellant Power Cartridges - Some Principles of Design" dated September 1960.

William M. Stowell
WILLIAM M. STOWELL
Lt Colonel, Ord Corps
Ord Corps (GM) Representative

1-Incl:
a/s

Copies furnished:
w/Incl: CofOrd(ORDTX)
CG AOMC
CO Picatinny Asnl
Dir. BRL
w/oIncl: CG ABMA
CG ARGMA
ArmA London for ACSI
File

If Inclosure is withdrawn the classification of this document will be downgraded to: UNCLASSIFIED

N.55136/B

Confidential MH
CONFIDENTIAL
MODIFIED HANDLING AUTHORIZED

14342

RESTRICTED

U.S. CONFIDENTIAL
BRITISH RESTRICTED

THIS DOCUMENT IS THE PROPERTY OF H.B.M. GOVERNMENT AND ATTENTION IS CALLED TO THE PENALTIES ATTACHING TO ANY INFRINGEMENT OF THE OFFICIAL SECRETS ACTS

It is intended for the use of the recipient only, and for communication to such officers under him as may require to be acquainted with its contents in the course of their duties. The officers exercising this power of communication are responsible that such information is imparted with due caution and reserve. Any person other than the authorised holder, upon obtaining possession of this document, by finding or otherwise, should forward it together with his name and address in a closed envelope to:—

THE SECRETARY, THE WAR OFFICE, WHITEHALL, LONDON, S.W.1.

Letter postage need not be prepaid, other postage will be refunded. All persons are hereby warned that the unauthorised retention or destruction of this document is an offence against the Official Secrets Acts.

U.S. CONFIDENTIAL
BRITISH RESTRICTED

RESTRICTED